CALIFORNIA ELECTRICAL CODE

GENERAL ELECTRICAL REQUIREMENTS

EXCEPTIONS TO THE RULES

There are exceptions to most rules in the California Electrical Code, sometimes even exceptions to the exceptions. Most of these exceptions apply to unusual circumstances which seldom occur in residential construction. For the sake of keeping it simple, we have chosen not to list all of the exceptions to the general rules covered in this guide.

COLOR OF CONDUCTORS

Neutral (grounded) conductors must have white or light gray insulation. If they are #6 AWG or larger, they need not have continuous white or light gray insulation, but can be marked at the ends with white tape. These colors are reserved for neutral conductors and must not be used for any other type of conductor.

Equipment grounding conductors must be bare or have green insulation. If they are #6 AWG or larger, they need not have continuous green insulation, but can be marked at the ends with green tape. This color is reserved for equipment grounding conductors and must not be used for any other type of conductor.

SIZE OF CONDUCTORS

The minimum size of conductors is shown in Table 310-16 from the CEC. The more current a conductor carries, the higher its temperature gets. The maximum allowable current load for each conductor is determined by the temperature rating of its insulation (shown in the column headings of the table). Copper conductors can carry more current than aluminum conductors of the same size (copper is on the left side of the table, aluminum is on the right).

Table 310-16. Allowable Ampacities of Insulated Conductors Rated 0 through 2000 Volts, 60° to 90°C (140° to 194°F) Not More Than Three Current-Carrying Conductors in Raceway or Cable or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)

Size	Temperature Rating of Conductor. See Table 310-13.						Size
	60°C (140°F)	75°C (167°F)	90°C (194°F)	60°C (140°F)	75°C (167°F)	90°C (194°F)	
	TYPES TW†, UF†	TYPES FEPW†, RH†, RHW†, THHW†, THW†, THWN†, XHHW† USE†, ZW†	TYPES TBS, SA SIS, FEP†, FEPB†, MI RHH†, RHW-2, THHN†, THHW†, THW-2†, THWN-2†, USE-2, XHH, XHHW† XHHW-2, ZW-2	TYPES TW†, UF†	TYPES RH†, RHW†, THHW†, THW†, THWN†, XHHW†, USE†	TYPES TBS, SA, SIS, THHN†, THHW†, THW-2, THWN-2, RHH†, RHW-2, USE-2, XHH, XHHW, XHHW-2, ZW-2	
AWG kcmil	COPPER			ALUMINUM OR COPPER-CLAD ALUMINUM			AWG kcmil
18	....	....	14	....	....	....	....
16	....	....	18	....	....	....	....
14	20†	20†	25†	....	....	....	....
12	25†	25†	30†	20†	20†	25†	12
10	30	35†	40†	25	30†	35†	10
8	40	50	55	30	40	45	8
6	55	65	75	40	50	60	6
4	70	85	95	55	65	75	4
3	85	100	110	65	75	85	3
2	95	115	130	75	90	100	2
1	110	130	150	85	100	115	1
1/0	125	150	170	100	120	135	1/0
2/0	145	175	195	115	135	150	2/0
3/0	165	200	225	130	155	175	3/0
4/0	195	230	260	150	180	205	4/0
250	215	255	290	170	205	230	250
300	240	285	320	190	230	255	300
350	260	310	350	210	250	280	350
400	280	335	380	225	270	305	400
500	320	380	430	260	310	350	500
600	355	420	475	285	340	385	600
700	385	460	520	310	375	420	700
750	400	475	535	320	385	435	750
800	410	490	555	330	395	450	800
900	435	520	585	355	425	480	900
1000	455	545	615	375	445	500	1000
1250	495	590	665	405	485	545	1250
1500	520	625	705	435	520	585	1500
1750	545	650	735	455	545	615	1750
2000	560	665	750	470	560	630	2000

CORRECTION FACTORS

Ambient Temp.°C	For ambient temperatures other than 30°C (86°F), multiply the allowable ampacities shown above by the appropriate factor shown below.						Ambient Temp. °F
21-25	1.08	1.05	1.04	1.08	1.05	1.04	70-77
26-30	1.00	1.00	1.00	1.00	1.00	1.00	78-86
31-35	.91	.94	.96	.91	.94	.96	87-95
36-40	.82	.88	.91	.82	.88	.91	96-104
41-45	.71	.82	.87	.71	.82	.87	105-113
46-50	.58	.75	.82	.58	.75	.82	114-122
51-55	.41	.67	.76	.41	.67	.76	123-131
56-60	....	.58	.71	....	.58	.71	132-140
61-70	....	.33	.58	....	.33	.58	141-158
71-80	....	....	.41	....	....	.41	159-176

†Unless otherwise specifically permitted elsewhere in this *Code*, the overcurrent protection for conductor types marked with an obelisk (†) shall not exceed 15 amperes for No. 14, 20 amperes for No. 12, and 30 amperes for No. 10 copper; or 15 amperes for No. 12 and 25 amperes for No. 10 aluminum and copper-clad aluminum after any correction factors for ambient temperature and number of conductors have been applied.

The following table is an exception to Table 310-16 for residential feeders and service entrance conductors only. This is based on the idea that residential loads are typically less continuous than nonresidential loads, allowing more cooling time for the conductors.

Conductor Types and Sizes
RH-RHH-RHW-THHW-THW-THWN-THHN-XHHW-USE

Copper	Aluminum or Copper-Clad Aluminum	Service or Feeder Rating in Amps
AWG	AWG	
4	2	100
3	1	110
2	1/0	125
1	2/0	150
1/0	3/0	175
2/0	4/0	200
3/0	250 kcmil	225
4/0	300 kcmil	250
250 kcmil	350 kcmil	300
350 kcmil	500 kcmil	350
400 kcmil	600 kcmil	400

ELECTRICAL CONNECTIONS

Connections of electrical conductors must be made with listed pressure devices such as wire nuts, split bolts, crimp connectors, clamping terminals, etc. This includes connections between grounding conductors. Simply twisting conductors together is not adequate. Soldering is only permitted after a connection with a listed pressure connector has already been made.

Aluminum conductors can only be connected using devices specifically listed for aluminum. The listing for these devices normally includes the use of anti-oxidation inhibitor on the conductors. This compound prevents the aluminum from oxidizing and becoming loose in the terminal or connector, which can cause arcing and fire.

All connections of conductors must be made in a listed enclosure or box. Splicing conductors outside of an enclosure and just taping them is never allowed.

WET LOCATIONS

Switches and receptacles installed in wet locations such as outdoors must be effectively protected from water. If the surface of the building is smooth, they can be installed in a flush-mounted box with a listed weatherproof cover. But if the building surface is too rough for the gasket provided with a weatherproof cover to form an effective seal, a weatherproof surface-mount box may be needed.

PROTECTION OF ELECTRICAL WIRING

Vegetation such as trees shall not be used for support of overhead conductor spans. See also GENERAL ROUGH WIRING REQUIREMENTS.

ELECTRICAL DESIGN REQUIREMENTS

CIRCUITS

The minimum number of circuits for lights and general purpose receptacles in a residence is based on 3 watts per square foot. The total number of watts is then divided by 120V to give the required number of amps. The total amperage of lighting and general purpose receptacle circuits, as determined by their circuit breaker ratings, must equal or exceed this number. The required kitchen, bathroom, and laundry circuits described below can't be counted toward this minimum.

At least two 20A circuits must be provided for counter and other receptacles in the kitchen and other food-handling areas. These circuits can't serve any loads other than receptacles in the food-handling areas. Outdoor receptacles are no longer allowed on these circuits.

Bathroom receptacles must be supplied by a dedicated 20A circuit. Any number of bathrooms can be supplied by one circuit, but no other outlets are allowed on it.

The laundry must also have a dedicated 20A circuit.

Clothes dryers normally have a 30A circuit and ranges usually have a 40A or 50A circuit, depending on the particular appliance to be installed.

RECEPTACLES

There is no specific limit to the number of receptacles which can be put on a residential branch circuit, but the CEC states that loads should be evenly proportioned among the circuits provided.

Receptacles must be installed in all habitable rooms so that an appliance with a 6' cord can be placed anywhere along the wall and be able to reach a receptacle without crossing a doorway, fireplace or similar opening and without using an extension cord. Stated another way, each wall space must have receptacles no more than 6' from each end and no more than 12' apart between end receptacles. A wall space may include any number of inside or outside corners, but ends at any door, fireplace, or other break in the wall across which a cord shouldn't be strung. Fixed room dividers are considered wall space, as are the fixed panels in multi-panel doors. But movable door panels mark the end of a wall space. Any wall space 2' or more in width needs at least one receptacle.

Countertops in food-handling areas must be provided with receptacles in accordance with the following rules:

- Any section of counter against a wall and 12" or more in width must have a receptacle within 24" of any point along the wall at the back of the counter. Counter sections separated by sinks or cooking appliances are considered separate sections.
- Island counters must have at least one receptacle.
- Any peninsula with two square feet or more of counter area, measured from the connecting edge, must have at least one receptacle.
- Receptacles must not be more than 18" above the countertop or in the case of islands or peninsulas, not more than 12" below it. Where receptacles are below the countertop, the countertop must not extend more than 6" beyond the base cabinet.

At least one receptacle must be installed in each of the following locations:

- In bathrooms at each basin location
- Outdoors in the front and back of the building
- At the clothes washer
- In basements
- In attached garages or detached garages with electricity
- In hallways 10' or more in length

- Within 25' of mechanical equipment and on the same level. This is a mechanical code requirement.

All receptacles in the following locations must be ground-fault circuit-interrupter receptacles, usually referred to as GFI receptacles:

- Bathrooms
- Garages
- Grade-level accessory buildings used for storage or work areas
- Outdoors
- Underfloor crawlspaces
- Basements other than habitable rooms
- Kitchen counter receptacles
- Counter receptacles within 6' of a bar sink
- Temporary power at construction sites

These receptacles can detect any current not following the normal path, which happens when a person get shocked, and shut off the electricity in milliseconds.

Receptacles installed on 20A circuits may be rated at 15A or 20A. But those installed on 15A circuits can't exceed a 15A rating. If a circuit serves only a single receptacle, the receptacle must be rated at least as high as the circuit breaker.

LIGHTING

At least one wall switch-controlled light must be provided in each of the following locations:

- All habitable rooms (used for living, sleeping, eating or cooking)
- Bathrooms
- Hallways
- Stairways - Any interior stairway with 6 steps or more must have a switch at each floor level.
- Attached garages and detached garages with electric power
- Outside of exterior doors
- Attics, underfloor spaces, basements and utility rooms if used for storage or if they contain equipment requiring servicing - The switch must be located at the point of entry.

No hanging light fixtures, lighting track or ceiling fans are allowed above bathtubs. Light fixtures installed in wet or damp locations must be marked as suitable for such locations.

Light fixtures in clothes closets must be at least 12" from a storage area, or 6" if they are recessed or fluorescent. Two storage areas are defined in clothes closets by the electrical code:

1) The lower storage area extends horizontally 24" from the back and side walls and vertically from the floor to 6' above the floor or to the highest clothes pole, whichever is higher.
2) The upper storage area extends horizontally 12" from the back and side walls or the width of the shelf, whichever is wider, and vertically from the top of the lower storage area to the ceiling.

This is a bit complicated, but generally speaking, the best place to put a light fixture in a clothes closet is on the wall above the door. If it must be on the ceiling, keep it away from shelves and clothes poles.

SERVICES AND SUBPANELS

Every electrical panel must have a permanently clear working space in front of it at least 30" wide, 3' deep and 6 1/2' high. This space can't be used for storage. For indoor panels, the working space must be lighted.

Circuit breakers or fuses are not allowed in bathrooms or in the presence of easily ignitable materials such as in clothes closets.

The loads controlled by each circuit breaker must be identified in a legible and durable manner on the panel.

OVERHEAD SERVICE DROPS

The general rule requires overhead service drop conductors to be at least 8' above a roof. If the roof is designed for human occupancy, such as a deck above enclosed space below, the clearance must be at least 10'. On the other hand, if the slope of the roof is 4:12 or steeper, the required clearance is reduced to 3'. This clearance may be further reduced to 18" above an overhang provided that the length of the conductors above the overhang doesn't exceed 4' measured horizontally or 6' measured along the slope of the conductor.

The conductors must be at least 12' above the ground, paving, or other surfaces accessible to vehicles. For surfaces accessible only to pedestrians, the clearance may be reduced to 10'.

Overhead service drops are installed by PG&E, but it is the property owner's responsibility to extend the service mast high enough to meet required clearances. PG&E standards call for bracing of a rigid metal conduit mast if its height above the roof exceeds 42" for 1 1/4" or 1 1/2" conduit, and 54" for 2" conduit.

DISCONNECTING MEANS

Every service panel and subpanel must be capable of being completely shut off with no more than 6 motions of the hand. This disconnecting means must be in or on the building served by the panel and must be readily accessible to the occupants of the building. Readily accessible means the panel cover must not be locked shut.

GROUNDING ELECTRODES

Each service must be provided with a grounding electrode. Two methods are commonly used to meet this requirement. In new construction, 20' of 1/2" (#4) or larger rebar embedded in the concrete footing can be used. It must be near the bottom of the footing and be surrounded by at least 2" of concrete. It is typically bent upward to project above the top of the foundation near the service. The 20' embedded portion need not be a single bar, but splices must be tight enough to assure good electrical contact. For existing buildings, a ground rod is usually used. It is a listed electrical product which must be driven at least 8' into the earth.

The wire which runs from the grounding electrode to the service is called the grounding electrode conductor. A typical 200A service in a new residence requires a 4 AWG copper grounding electrode conductor. Minimum sizes for larger and smaller services can be found in Table 250-94 in the 1998 CEC. The connection of this conductor to the grounding electrode must be permanently accessible. The grounding electrode conductor or the conduit in which it runs must be securely attached to the surface of the building or structure if exposed. If it runs in conduit, the ends of the conduit must be securely attached to the grounding electrode and the service enclosure. This requires a special clamping device at the grounding electrode which clamps the conductor and the conduit separately.

A subpanel in a garage or other detached accessory building, which is fed by the main service at the house, must have a separate grounding electrode. If the feeder from the main service is only 3 wires (2 hots and neutral) the grounding electrode conductor at the subpanel must be bonded to the neutral. If the feeder has four wires (2 hots, neutral and ground) the grounding electrode conductor at the subpanel must be isolated from the neutral, even though they are bonded together at the main service. This seems odd, but there is a good reason

for it. If you cut the neutral wire of an active circuit and hold one cut end in each hand, you will be electrocuted. If you do it to a properly installed ground wire, you will not. But when you bond the neutral and ground together, the ground wire from that point back to the beginning of the circuit shares the current carried by the neutral and can electrocute you. For that reason, the bonding together of these two wires must only occur at the origin of the ground wire.

BONDING WATER AND GAS PIPES

Metal water pipes must be bonded to ground at the main service. This is not to ground the service, which must be grounded by other means discussed above, but rather to make sure that the water pipes are grounded. If the water pipes should become energized, the current will take the path of least resistance to ground. By bonding them to a reliable ground at the service, the current will be more likely to go there instead of through a person who might touch the energized pipe. The conductor used for this purpose must be the same size as required for the grounding electrode conductor. The connection of this conductor to the pipe must be permanently accessible.

Gas pipes must also be bonded to ground at the service for the same reason as the water pipes. A single conductor is often used to bond both, passing through the connector at the first pipe without splice, and continuing to the connector at the second pipe.

Before PG&E can energize a new electric service, it must be inspected and approved by the Building Division. In new construction, a completed receptacle outlet must be provided before this can occur. If the rough wiring is still exposed it's considered temporary and the receptacle must be GFI protected.

ROUGH WIRING

GENERAL ROUGH WIRING REQUIREMENTS

Single conductors are only permitted in conduit or in a sheathed cable assembly. When run in conduit, all conductors of the same circuit, including the equipment ground, must be in the same conduit.

Holes in framing members for cables or conduit must be at least 1 1/4" from the edge of the member. If they aren't, a steel safety plate, at least 1/16" thick, must be attached to the edge of the member to protect the wiring from nails and other fasteners. Holes in steel framing members used for non-metallic sheathed cable must have bushings or grommets securely fastened in them. Cables or conduits which run parallel to framing members must be securely supported at least 1 1/4" from the face of the member or protected along their entire length by a steel plate or sleeve at least 1/16" thick. The requirements in this paragraph don't apply to the following types of conduit: 1) rigid metal conduit, 2) intermediate metal conduit, 3) rigid nonmetallic conduit, and 4) electrical metallic tubing.

Wires should not be bundled, since it interferes with dissipation of the heat they produce when carrying current. The codes allows bundling for no more than 24", which allows getting through choke points such as the hole(s) in the wall plates at electrical panels.

All boxes and other enclosures containing splices, connections, or ends of conductors must be permanently accessible.

GROUNDING

All noncurrent-carrying metal parts of electrical enclosures, boxes and conduits must be grounded. Failure to properly ground metal boxes is a common correction in the field. The code says "Sheet-metal screws shall not be used to connect grounding conductors to enclosures." It goes on to say that the connection must be made "...by means of a *[green]* grounding screw that shall be used for no other purpose, or a listed grounding device." A box cannot be grounded only by the installed receptacle, switch, light fixture, etc. Unthreaded conduit must be bonded to enclosures with bonding locknuts or bushings. Standard locknuts and bushings don't provide an adequate connection.

All grounding conductors in a box must be tied together in such a manner that the removal of the device installed in the box will not interrupt the grounding continuity. This must be completed at the rough wiring inspection, since it will be concealed at final inspection.

In addition to the grounding requirements above, an equipment grounding conductor must be attached to the device installed in a box. This conductor must also be in place at rough wiring inspection.

In previous editions of the CEC, it wasn't necessary to run a dedicated equipment grounding conductor to ranges and dryers. They could be grounded by means of the insulated neutral conductor. This is no longer the case. Both ranges and dryers must have a separate equipment grounding conductor (green insulation or bare) in addition to the insulated neutral (white) and two hot conductors. This also means 4-prong receptacles are now required for these appliances.

UNDERGROUND CONDUCTORS

Only type USE conductors and type UF cable can be direct-buried in the earth. All other underground conductors and cables must be in conduit. Direct-buried conductors must have at least 24" of cover on top of them. The required cover can be reduced to 18" when the conductors are in conduit approved for burial, normally rigid nonmetallic conduit. Where underground conductors emerge from the ground, they must be protected with conduit from the required underground depth to the point where they enter the building. Where direct buried conductors enter this conduit they must be protected from the edge of the conduit by a bushing or other device listed for the purpose.

TYPE NM CABLE

Type NM cable, often called "Romex", is the most commonly used wiring method in residential construction. It should only be used in dry locations. Where subject to physical damage it must be protected. This applies to garages, unfinished basements, and other places where the framing is exposed and the wiring is installed less than 8' above the floor. It also applies to attic wiring within 6' of an attic access opening. The radius of the inner edge of bends must not be less than 5 times the cable diameter. When the cable is not round, the largest dimension is considered the diameter.

Type NM cable must be supported with listed staples or similar devices at least every 4 1/2 feet and within 12" of every cabinet, box or fitting which it enters. It must also be clamped with a listed device where it enters these enclosures. There is one notable exception to this last requirement: it may enter a single-gang non-metallic box without being clamped if it is secured within 8" of the box. In all cases, the cable sheathing must extend beyond the clamp or opening into the box at least 1/4". Cables passing through holes in framing members are considered supported.

Even though the individual conductors in type NM cable must be rated 90°C, the cable assembly is not allowed to operate at temperatures higher than 60°C. The maximum ampacity ratings can be found in the 60°C columns of Table 310-16 shown above. In plenums and other air-handling spaces, type NM cable can only be run perpendicular to the air flow.

WIRING IN ELECTRICAL BOXES

Neutral conductors must be spliced together in boxes so that removal of the switch, receptacle, light fixture, etc. will not interrupt the continuity of the circuit. This is similar to the requirement for grounding conductors described above.

The ends of all conductors entering boxes must have sufficient length to project at least 6" beyond the face of the box. Without this length, the necessary splices and terminal connections can't be made in a safe strain-free manner. The extra length is normally "folded" into the box in a zigzag manner so that it ends up in the back of the box.

The CEC limits the number of conductors which can enter a box based on the interior volume of the box, the sizes of the conductors, the presence of internal cable clamps or support fittings, and the number of switches or receptacles. The actual calculations can be complex, but as a rule of thumb, if you have trouble fitting everything into the box in a safe and orderly manner, the box is probably too small. Extensions are available for most electrical boxes which can solve this problem.

Unused openings in electrical enclosures must be effectively closed in a manner which provides protection similar to the wall of the enclosure. Listed plugs are available to meet this need.

Boxes installed in wood-framed walls and ceilings must be flush with the finished surface.

SWIMMING POOLS AND SPAS

OUTDOOR POOLS, INDOOR POOLS, AND OUTDOOR SPAS

A 110V receptacle must be installed no less than 10' and no more than 20' from the water's edge. Any receptacle less than 20' from the water must be protected by a GFI. No receptacles are permitted less than 10' from the water.

Lights and ceiling fans must be at least 5' horizontally from the water or 12' above it. Lights between 5' and 10' from the water must be GFI protected and securely mounted on a wall or equally rigid structure.

Switches must be at least 5' from the water unless separated from the pool or spa by a wall, fence, or similar structure.

Overhead electrical conductors must be at least 18' above the water level throughout an area extending 10' beyond the water's edge in all directions. They must also be at least 14' above all diving boards and other structures associated with the pool.

INDOOR SPAS

A 110V receptacle must be installed no less than 5' and no more than 10' from the water's edge. Any receptacle less than 10' from the water must be protected by a GFI. No receptacles are permitted less than 5' from the water.

Lights and ceiling fans must be at least 5' horizontally from the water or 7' 6" above it and GFI protected.

Switches must be at least 5' from the water.

JETTED BATHTUBS

The difference between a spa and a jetted bathtub per the CEC is that a bathtub is normally drained after each use and a spa is not.

Receptacles within 5' of jetted bathtubs must be GFI protected. This includes the receptacle serving the pump motor.

NOTE: There are also important regulations for the prevention of child drownings by installation of pool and spa enclosures. Please contact the Building Division for more information if you are contemplating installation of a pool or spa.